Renewable Energy Trends 2000

Arthur D Little

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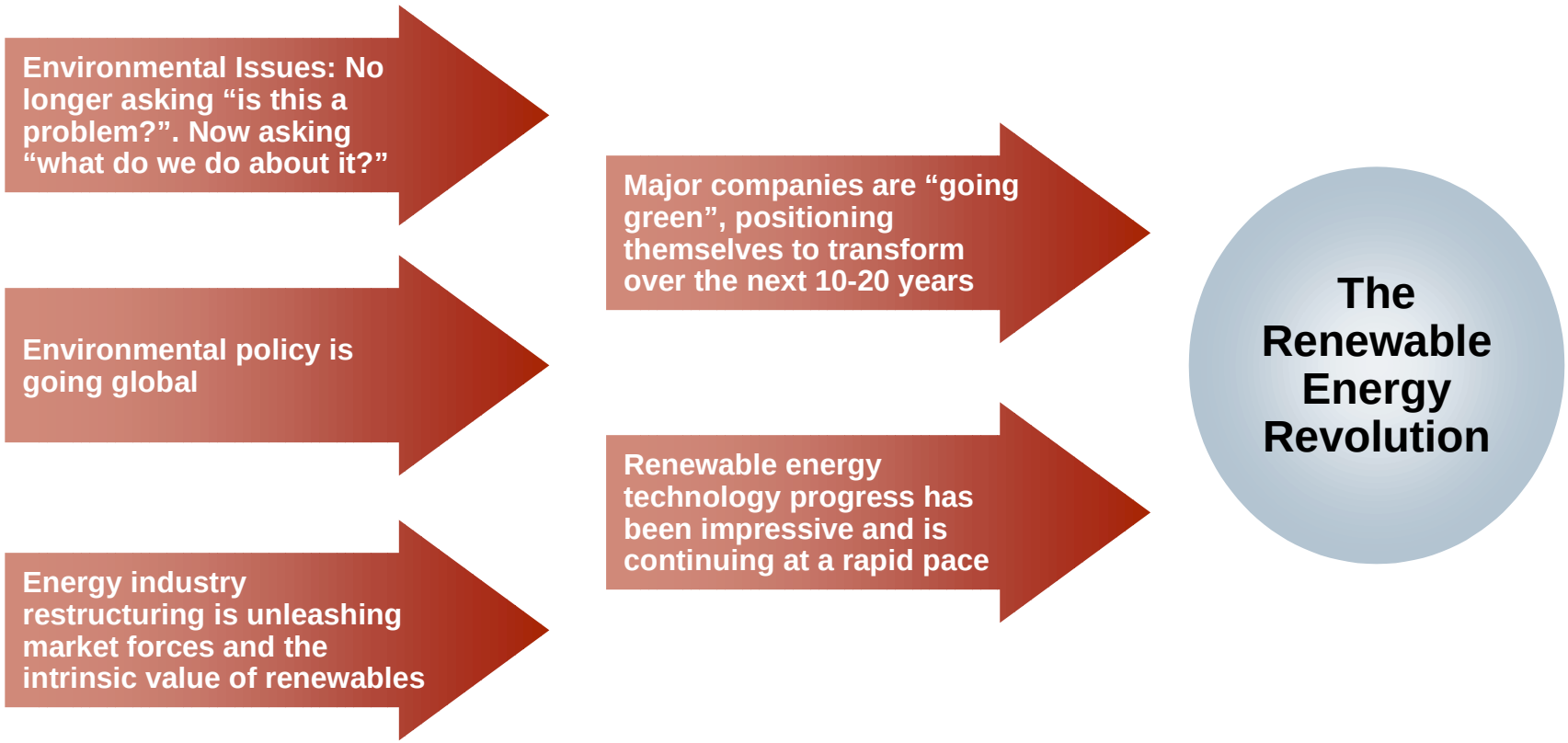
Contents

This document reflects ADL's current thinking on the major trends in renewable energy that are likely to affect your business.

- Its two major purposes are to create a tool for creative thinking around the rapidly changing renewable energy industry and to provide a context within which strategic thinking can be checked.
- It is a distillation resulting from numerous cases that Arthur D. Little staff have been involved with worldwide over the last several years.
- These trends are based on experience - a number of factors can influence the speed and direction of these trends and the accuracy of any predictions.
- This document is being continually reviewed and updated as trends evolve and change.
- This trends document is complemented by *Utilities Trends* and *ISO Trends* documents.

A number of factors are aligning to create unprecedented opportunities for renewable energy and the companies that best exploit it.



Renewable energy trends raise three different classes of questions.

Government & Regulatory

- Will deregulation and market forces result in a boom or bust for renewable energy?
- Will holistic solutions replace narrowly-defined regulations?

Technology Progress

- Can renewable energy compete in the marketplace, or is it still a pipe-dream?
- What key technologies could be deal-changers for renewable energy?
- What impact could a hydrogen economy have on renewable energy, and how likely is that scenario?

Business Impact and Response

- Is rapid growth in renewable energy a business fad or positioning for the future?
- Does green image and branding have real business value?

Will deregulation and market forces result in a boom or bust for renewable energy?

Answer

Government "command and control" still represents a dominant driver for the renewable energy industry, but the trend is increasingly to unleash market forces to achieve policy objectives.

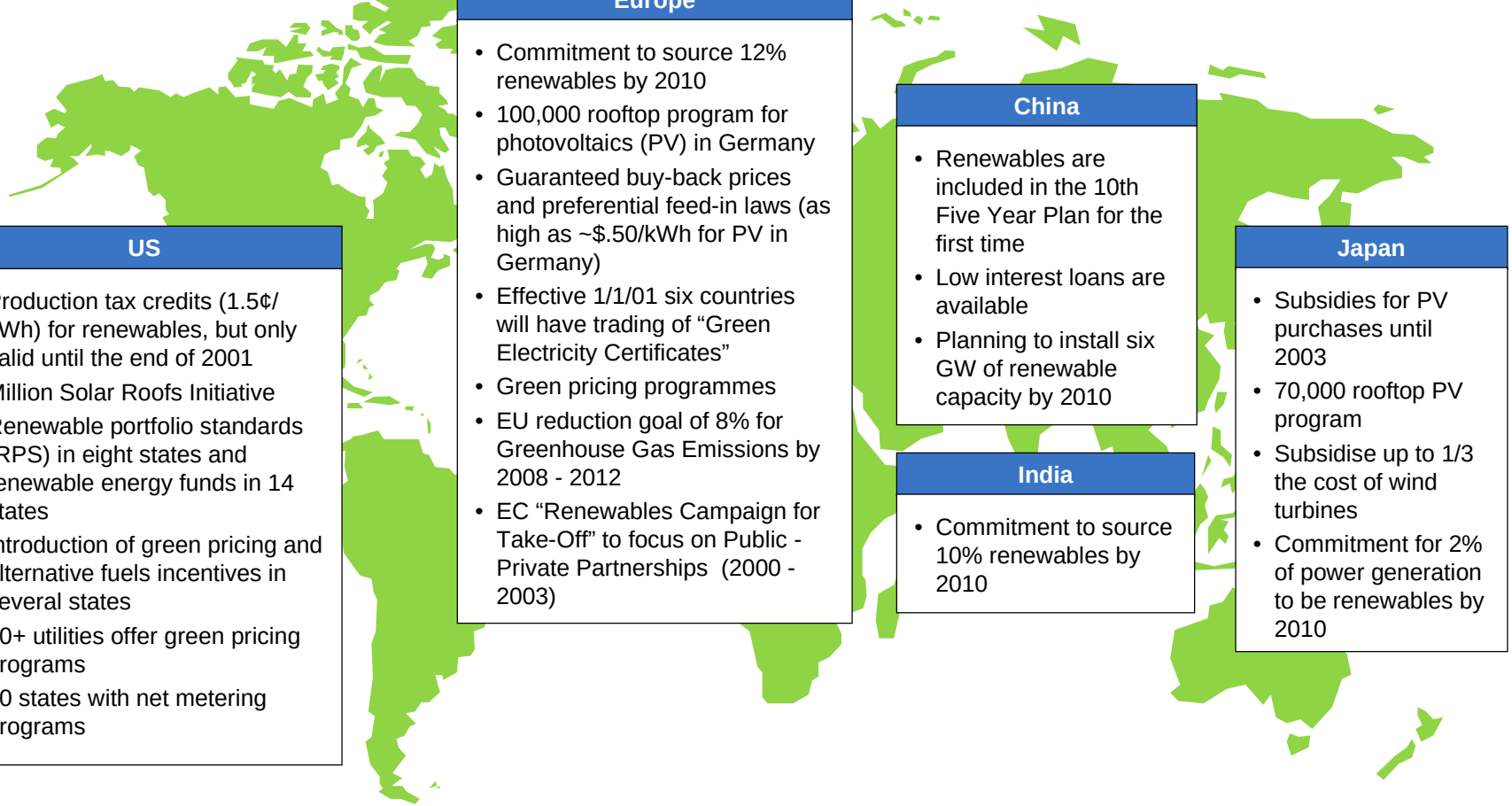
Pros

- Allows for the exploitation of the unique attributes of renewable energy and opens opportunities for companies to find creative solutions
  - e.g., burning biomass to meet SO_2 reduction requirements (versus installing scrubbers), installing PV in urban areas to meet peak demand and relieve constraints (versus adding peaking capacity at a central station or upgrading T&D)
- Removes a crutch that some have argued simply props up technologies that have no chance of success on their own.

Cons

- Removes existing technology-specific incentives and support for renewables that are not currently cost competitive, but may be very important if the technologies show long-term promise
  - e.g., biomass plants in California have closed after their power purchase agreements have expired
- In response to this more competitive environment, new mechanisms are being created to continue government support for renewables.
  - Tax credits & focused technology R&D are being replaced with market-based incentives (e.g., system benefits charges, renewable portfolio standards, green certificates)
  - Cap & trade mechanisms are being considered for CO_2 reduction under the Kyoto Protocol
  - Labeling and disclosure will facilitate choice by letting people know how their power was generated

Many governments are putting specific policies and initiatives in place to increase the percentage of electricity generated by renewables.



US

- Production tax credits (1.5¢/ kWh) for renewables, but only valid until the end of 2001
- Million Solar Roofs Initiative
- Renewable portfolio standards (RPS) in eight states and renewable energy funds in 14 states
- Introduction of green pricing and alternative fuels incentives in several states
- 80+ utilities offer green pricing programs
- 30 states with net metering programs

Europe

- Commitment to source 12% renewables by 2010
- 100,000 rooftop program for photovoltaics (PV) in Germany
- Guaranteed buy-back prices and preferential feed-in laws (as high as ~$.50/kWh for PV in Germany)
- Effective 1/1/01 six countries will have trading of “Green Electricity Certificates”
- Green pricing programmes
- EU reduction goal of 8% for Greenhouse Gas Emissions by 2008 - 2012
- EC “Renewables Campaign for Take-Off” to focus on Public - Private Partnerships (2000 - 2003)

China

- Renewables are included in the 10th Five Year Plan for the first time
- Low interest loans are available
- Planning to install six GW of renewable capacity by 2010

India

- Commitment to source 10% renewables by 2010

Japan

- Subsidies for PV purchases until 2003
- 70,000 rooftop PV program
- Subsidise up to 1/3 the cost of wind turbines
- Commitment for 2% of power generation to be renewables by 2010

Note: Examples given are not exhaustive within countries or regions and many other countries are not listed

Will holistic solutions replace narrowly-defined regulations?

Answer

Renewables are increasingly seen to provide solutions to multiple problems that have traditionally been addressed one at a time

- Complicated layers of laws and regulations have been built up over many years and in some cases are at cross purposes.
  - e.g., European countries have provided a tax structure to encourage diesel fuel use in automobiles for energy security, but are now realizing that this is at odds with agendas for urban air quality.
  - The U.S. EPA regulates new power plants with strict standards to limit new sources of pollution, while many old, dirty coal plants were grandfathered by the Clean Air Act in recognition of the adverse economic impacts of shutting these plants down. This places new, clean technologies (e.g., gas turbines, renewables) at a disadvantage, despite the obvious emissions benefits.
- Renewables are increasingly being recognized as addressing multiple problems
  - National energy security, local air emissions, climate change, balance of trade, local economic development
- With this recognition have come a growing array of public/private partnerships.
  - e.g., PNGV, the link between clean fuel and clean vehicles, multi-national CO_2 trading

Among other European countries, Denmark is phasing out technology specific programs in favor of broader-based support mechanisms.

Example: Danish Market-Based, "Holistic" Policy

- The government is repealing subsidies and instituting market-based incentives for renewable energy technologies
- Transitional rules are being put in place to manage the shift toward market mechanisms (e.g., electricity surcharges).
- Each renewable energy producer will be allocated a certain number of renewable energy certificates, which must be purchased by all consumers. These serve as a premium for renewable energy.
- If consumers do not purchase their shares of the certificates, a 3.4¢/kWh penalty must be paid into a Renewable Energy Fund for every kWh for which a certificate should have been purchased. The Fund will then purchase all remaining certificates, thus ensuring a floor price for the certificates and that the entire market for certificates will clear.
- Denmark is also instituting a CO_2 cap, opening up the possibility of CO_2 trading, both nationally and internationally.

Sources: Acts of the Danish Parliament numbers 375, 376, 377 and 378.

Can renewable energy compete in the marketplace, or is it still a pipe-dream?

Answer

Renewable energy technology progress has been significant. Many technologies are competitive in niche applications today, and some are "knocking on the door" of mainstream markets.

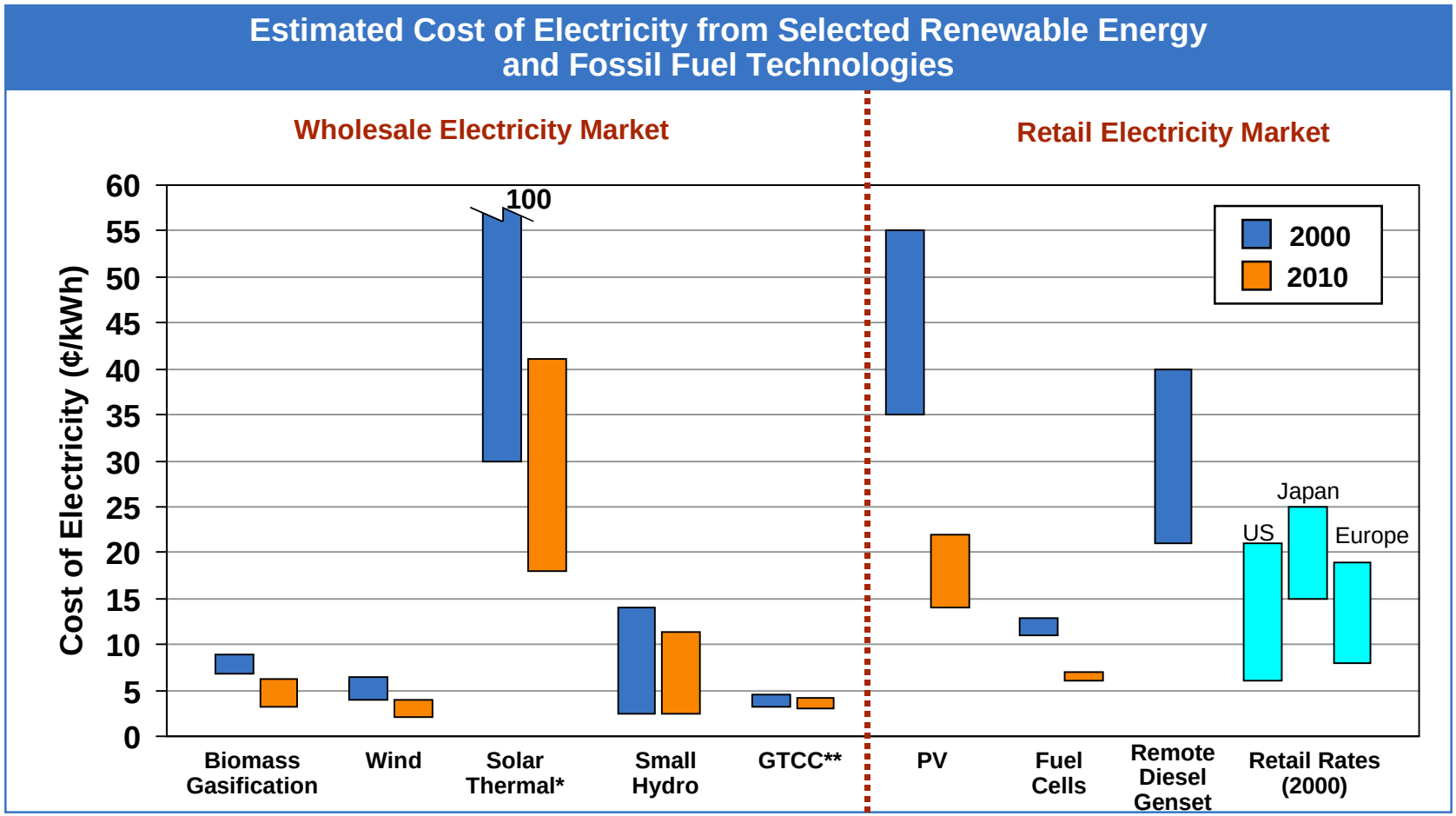
Technology progress has assumed several forms…

- Efficiencies and manufacturing capacities have increased, reducing the high first cost of many renewable energy technologies.
- Advances in balance of system technologies have helped to reduce costs and make systems operate more efficiently (e.g. variable speed drives in wind systems, improved inverter technology).
- Advanced materials for technologies have helped to improve performance (e.g., wind turbine blades and towers, photovoltaic modules).
- O&M costs have decreased due to economies of scale, experience, and technological improvements.
- Ethanol fuel is poised to make a major shift from corn-based to cellulose-based production technology
- Lessons learned have helped to optimize plant operations and in-field performance.

… with significant implications for the industry

- Renewables are increasingly carving out niche markets and sales of some are growing at 20-40% per year, most notably wind and PV.
- Some renewables, such as wind power, are approaching par on cost with conventional options
- This trend can and must be sustained for renewables as a whole to become competitive with ever-improving fossil fuel technologies.

Renewable energy technologies are approaching cost competitiveness with conventional power at the wholesale and retail levels.



* Includes dish Stirling, parabolic trough, & power tower
** Gas turbine combined cycle

What key technologies could be deal-changers for renewable energy?

Answer

Several "cross-cutting" technologies have seen dramatic cost reductions and performance enhancements in recent years, and may improve the competitive position of all renewables.

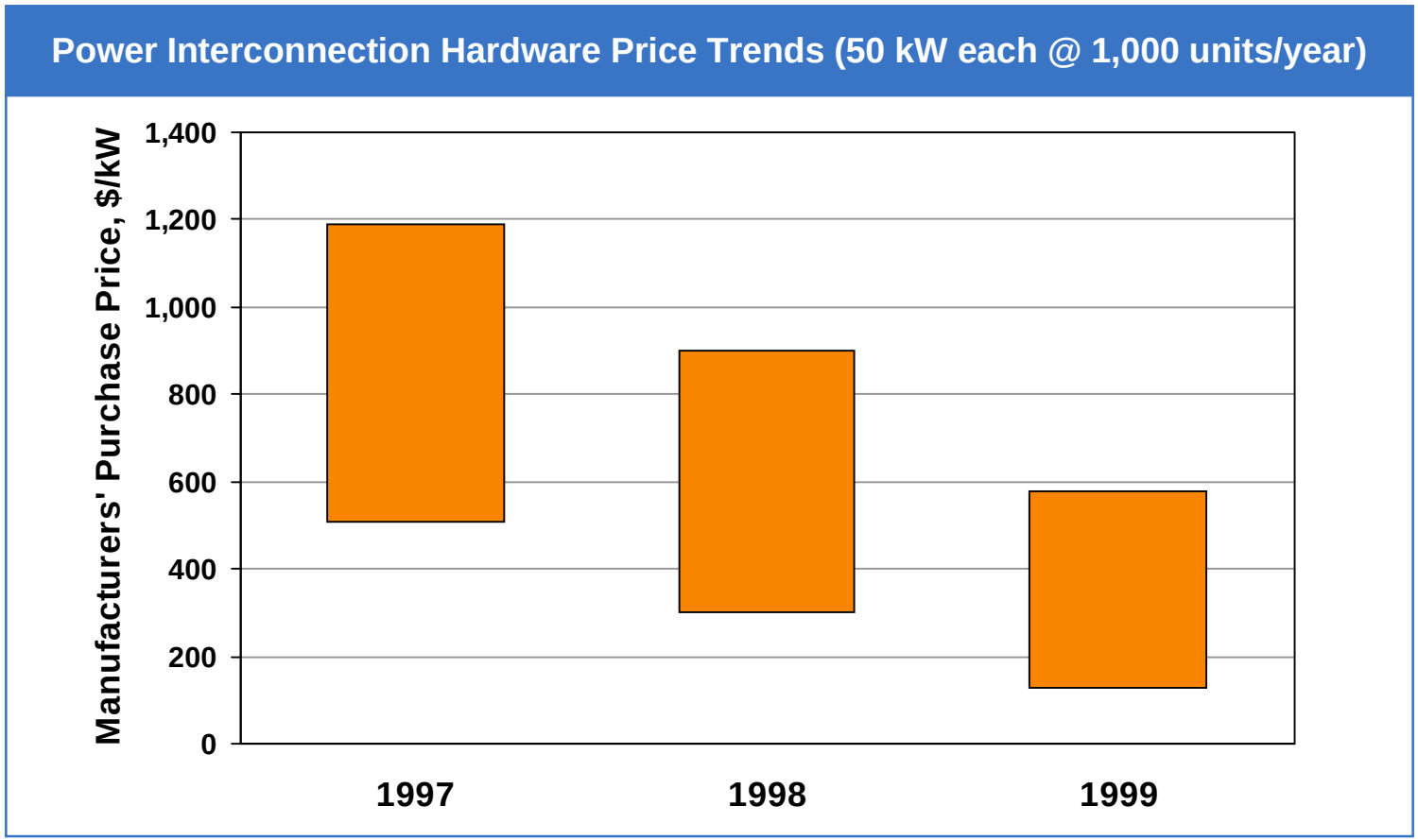
Renewables are going high-tech…

- The cost of power electronics associated with inverters required to interconnect DC sources (wind, fuel cells, PV) to the grid has fallen dramatically in recent years, and is poised for further reductions as distributed power technologies come to market.
  - Dramatic further price reductions are available through increased production volume.
- New and improved energy storage technologies are a boon to all renewable power technologies that are subject to intermittent operation.
  - PV and wind are especially affected by the cost of energy storage.
  - Reversible fuel cells may soon be competitive with batteries in some select applications.
- Advances in telecommunications allows for remote monitoring and dispatch, enabling renewables to respond to real-time price signals, and/or to preferentially dispatch green power.
- These same cross-cutting technologies are also creating substantial interest in distributed generation (DG) in general, which is setting up a positive feedback loop between fossil DG and renewables. Each stands to gain from the other's success

… but are still hampered by institutional barriers

- Uniform and simple interconnection standards throughout the United States and elsewhere are required to improve the viability of small-scale renewable power generators.
  - "Plug-and-Play" interconnection equipment will make packaging simpler and less expensive, and significantly reduce the costs and barriers to implementing small-scale power generation

Interconnection costs for renewables, driven by power electronics costs, have seen dramatic price reductions in the last several years.



Note: Range of vendor quotes shown from annual ADL reviews of power interconnection hardware prices for 50 kW fuel cell power systems. Prices shown are for products that include all interconnection functionality, from DC to grid-compatible AC (inverters, phase-matching, switchgear, safety, etc.). Specific quotes for each vendor have been intentionally obscured at vendors' requests.

What impact could a hydrogen economy have on renewable energy, and how likely is that scenario to unfold?

Answer

The zero-carbon, hydrogen economy could create additional demand for renewable energy, but has been hampered by the "chicken-or-egg" problem between hydrogen demand and hydrogen supply.

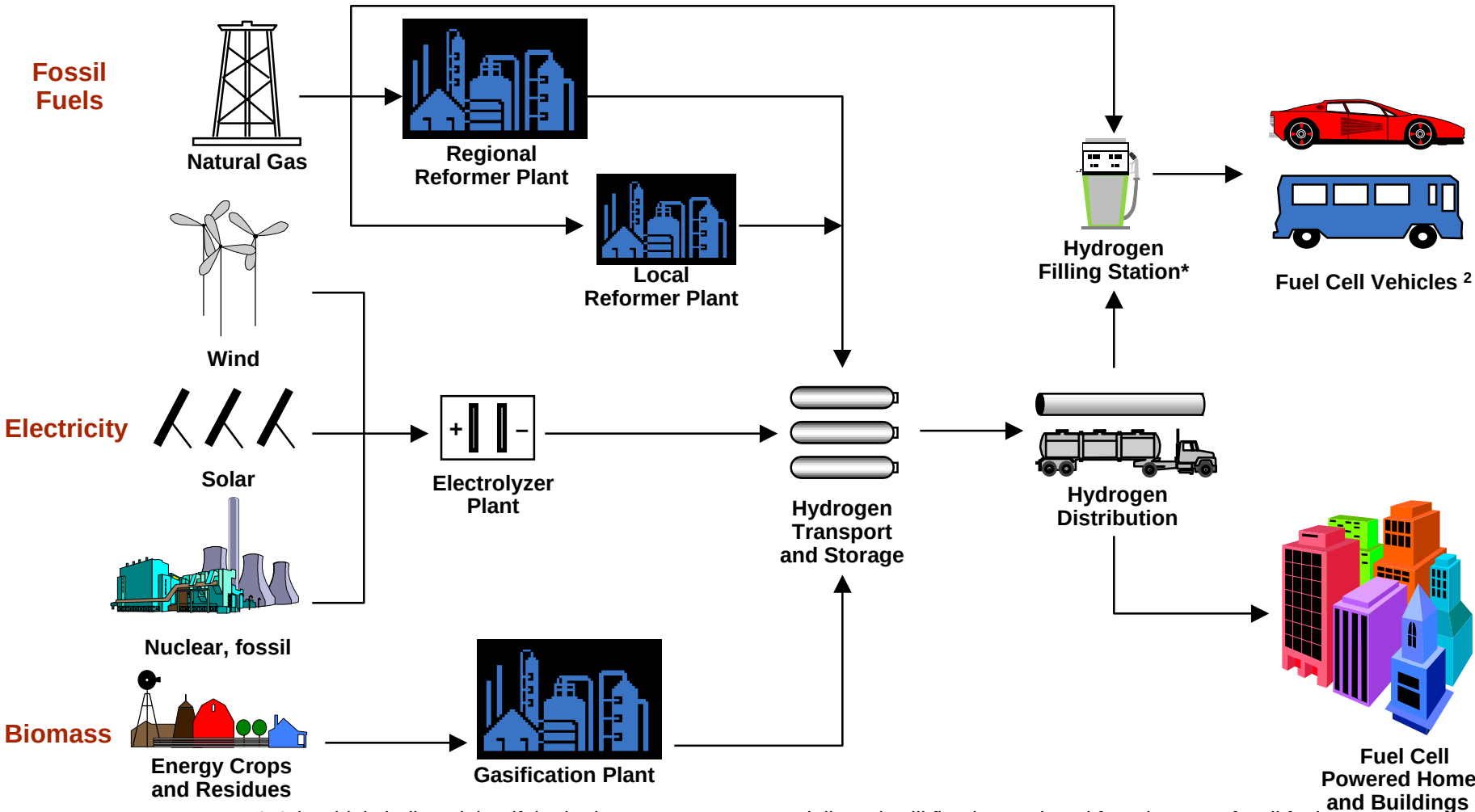
The hydrogen economy has been talked about for decades with limited movement…

- The long-term vision of the hydrogen economy is one in which renewable energy is used to produce hydrogen, which can then be distributed as a fuel, thereby completely eliminating emissions of CO_2 and most, if not all, criteria pollutants (CO, NOx, SOx, VOCs)
- Fundamental economics and the sheer magnitude of the infrastructure investment have been the major barriers
- Today, hydrogen is used only as an industrial gas or rocket fuel

… but a new pathway is emerging to resolve the chicken-or-egg problem

- Fuel cells may become a significant electricity generation technology over the next 10-20 years.
- Fuel cells place real value on hydrogen as an energy carrier. As they enter the market, they could stimulate demand for hydrogen.
- Even though the first generation of fuel cells will operate on fossil fuels (or fossil fuel-derived hydrogen), their success could lead to substantial political support for renewable hydrogen.
  - Japan, Canada, Iceland and some European countries have already begun to explore the possibility of hydrogen production via low-cost, renewable electricity (typically geothermal or hydro), which could then be transported to geographic regions with high-value electricity or transportation fuel needs.
- In addition to water electrolysis using renewable electricity, hydrogen could one day be made by direct microbial conversion of sunlight

Hydrogen can be made from any energy source[1] and at virtually any scale. It can then be used to power homes, businesses and vehicles.



1 It is widely believed that if the hydrogen economy materializes, it will first be produced from low-cost fossil fuels
2 May also fuel with conventional or alternative fuels and generate hydrogen on board.
3 May produce hydrogen onsite from natural gas or electrolysis, or receive hydrogen made elsewhere.

Is rapid growth in renewable energy a business fad or strategic positioning for the future?

Answer

The combination of favorable policies, consumer demand and technology advances is driving innovative business responses.

- Leading companies recognize the long term business value of renewable energy and are forming strategic alliances.
  - Major players are entering the renewables arena from other industries, including upstream energy and glass companies.
  - Partnerships, mergers and acquisitions are increasing as companies vie for a major role.
  - The trend is away from traditional market assessments toward development of business strategies that will establish a strong presence in the renewable energy industry
- Customer choice has enabled the proliferation of green power products and premium pricing schemes, and leading companies are now marketing and selling renewable energy.
  - Initial marketing investments are high, reflecting the steep learning curve as the public adjusts to choice, and begins to understand the connection between energy and environment.
  - Standards have been put in place to prevent false marketing, and demand will increase as customers gain experience , knowledge, and confidence in green power.

Major corporations are entering the business, and significant consolidation is occurring as large companies invest in smaller innovative companies.

Major Players, Mergers and Acquisitions

PV

- Shell Renewables
- Sharp
- Sanyo
- Kyocera
- Bekaert with ECD/United Solar
- Apogee Enterprises (glass coatings) with TerraSun
- BP Solar (BP and Amoco)

Fuel Cells

- Plug Power (GE Microgen)
- Siemens-Westinghouse
- Ballard Power Systems (Daimler-Chrysler/Ford/ GPU/Ebara/Alstom)

Green Power

- BP Amoco investment in Greenmountain.com
- Enron/ATT/AOL are creating the New Power Company

Wind

- Enron (Zond Systems/Tacke GmbH)
- NEG Micon (Wind World/Ned Wind)
- Gamesa Eolica (Vestas/Gamesa Group/Sodena

Hydrogen

- Texaco acquisition of 20% of Energy Conversion Devices

Companies are moving beyond traditional “wait and see” market assessments and developing business strategies to define their role in renewable energy.

Consumer demand for green power has led many companies to develop electricity products for sale into deregulated markets.

1 All products shown can be purchased via the internet.

Green-e certification was developed to assure consumers that the green electricity products they purchase are legitimate.

Does green image and branding have real business value?

Answer

Many companies have been re-branded as environmentally proactive, rather than environmentally neutral (or worse).

- Historically, if a company's environmental actions were publicized, it was only to report a negative event.
  - Markets still remember the events (and companies) associated with single words - Bhopal, Valdez, etc.
- Over the last 5 - 10 years, corporations have begun to take more proactive steps to create a corporate-wide green brand.
- When successfully implemented, these steps include both superficial re-branding as well as concrete displays of environmental stewardship.
  - Many companies accept climate change science and have publicly withdrawn from coalitions that oppose climate change policies
  - The purchase of green power (often at a price premium) for corporate headquarters and business operations has been used by many companies to help demonstrate their commitment.
  - Some companies, such as BP, have created internal programs to reduce CO_2 emissions, in part to stay ahead of potential future regulations.

Two-thirds of consumers say that if price and quality are equal, they are likely to switch to a brand associated with a good cause.

BP Amoco has committed to reduce CO_2 by 10% relative to 1990 by 2010, in part through the development and use of renewable energy. BPA is incorporating solar power at 200 service stations.

New Belgium Brewing Company's Colorado brewery is powered by 100% wind energy through Fort Collins Utilities Wind Power Program.

Birkenstock Footprint Sandals, Inc.: US Headquarters(CA) and Flagship store (CA) use 100% renewable power.

BJ's Wholesale Club: Pennsylvania store donated roof space for 1,400 Solar Panels (43 kW)

Fetzer Vineyards installed a solar rooftop system (40kW); remaining load supplied from PG&E "Clean Choice 100" renewable energy program.

Bentley Mills (major textile company) has installed the largest industrial (majority) privately-funded solar system (127 kW.)

Patagonia purchases 100% of their electricity from new wind power projects in California. This, combined with their use of organically grown cotton strengthens their branding as a green company.

Toyota Motor Sales: Leaf-Car logo symbolizes environmental commitment. Largest single user of renewable energy-- southern California facilities powered by 100% renewables from Edison "Earthsource 100" blend.

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Renewable Energy Trends

ADL Experience

Arthur D. Little Renewable Energy Project Experience

Selected Examples

ADL developed a broader based renewables strategy for a leading multinational energy company.

The Challenge

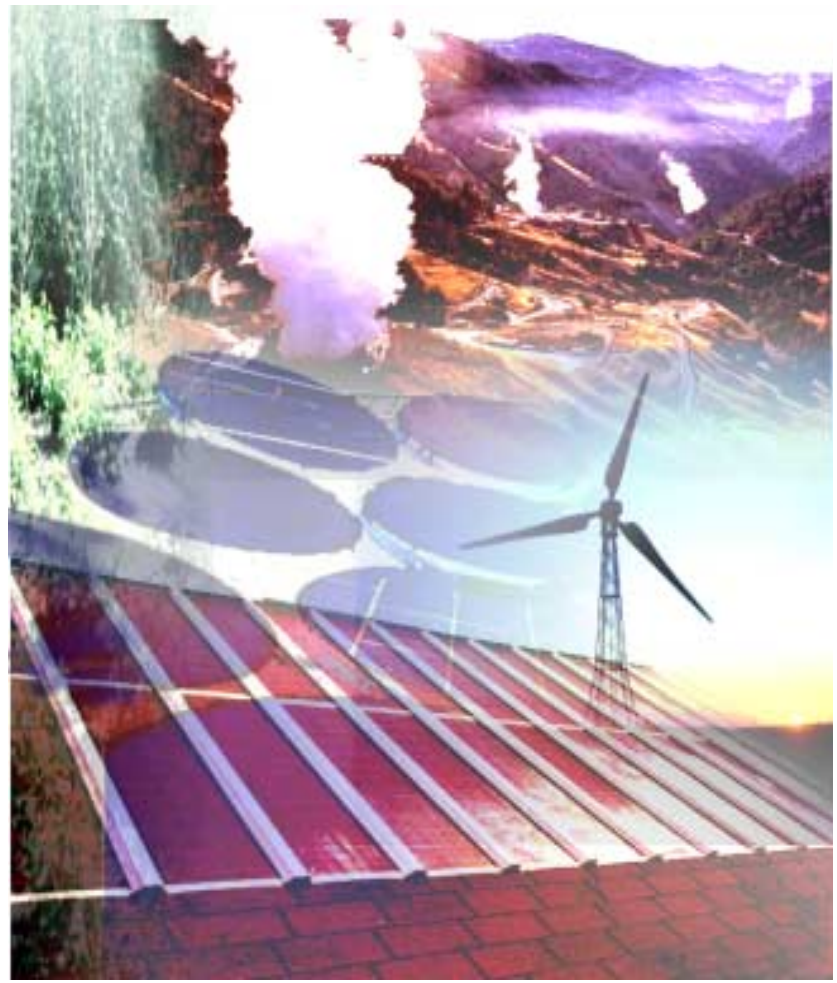
To develop a broad based renewable energy strategy for a multinational energy company

The Approach

- Review existing and future renewable technology options including a breakdown of the entire value chain for each technology
- Assess potential global markets for renewable energy and provide an understanding of the drivers and barriers for growth
- Predict future growth projections for each technology up to 2020 and cost projections to 2010
- Determine strategic fit with the existing business portfolio and identify optimal routes forward

The Result

Our client is implementing a broad based renewables strategy which is aligned with its existing business. This new business venture is expected to produce substantial growth and value creation



For a major oil company, ADL reviewed the competitive position of their PV product in developed and less developed countries and recommended a new business strategy.

The Challenge

To assess the competitiveness of a unique photovoltaic product

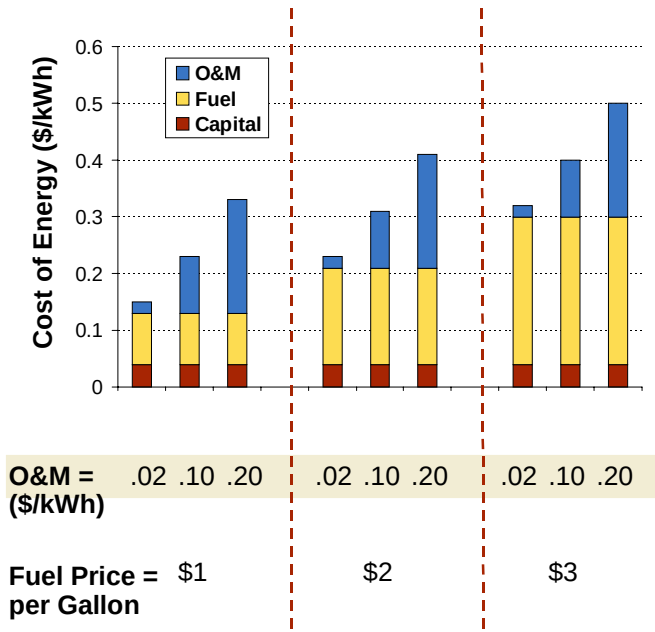
The Approach

- Estimate cost of energy for
  - Solar dish/Stirling
  - Solar parabolic trough
  - Solar power tower
  - Flat plate PV
  - Concentrator PV
  - Wind
  - Small diesel engines
- Identify renewable energy opportunities in developed and developing countries
- Identify target markets

The Result

Based on Arthur D. Little's recommendation, the client is changing their business strategy for their product.

Breakdown of Diesel Engine Cost of Energy Relative to Cost of Fuel and O&M Costs (Capital Recovery = 0.16)



For a major PV company, ADL optimized manufacturing processes to bring costs in line with market prices.

The Challenge

To reduce manufacturing costs to allow the company to be competitive in the PV market

The Approach

- Conduct an audit of manufacturing operations
- Benchmark operations against industry
- Apply best practices to:
  - Purchasing
  - Manufacturing productivity
  - Asset utilization
  - Organization
- Prioritize cost-reduction opportunities
- Develop implementation plan with client team

The Result

Arthur D. Little gave the client a concrete implementation plan to save $2.8 million per year with an initial investment of $3.1 million

For a European transportation component supplier, ADL evaluated opportunities for entering the wind energy business.

The Challenge

To evaluate potential synergies between the company's current business and the wind power industry.

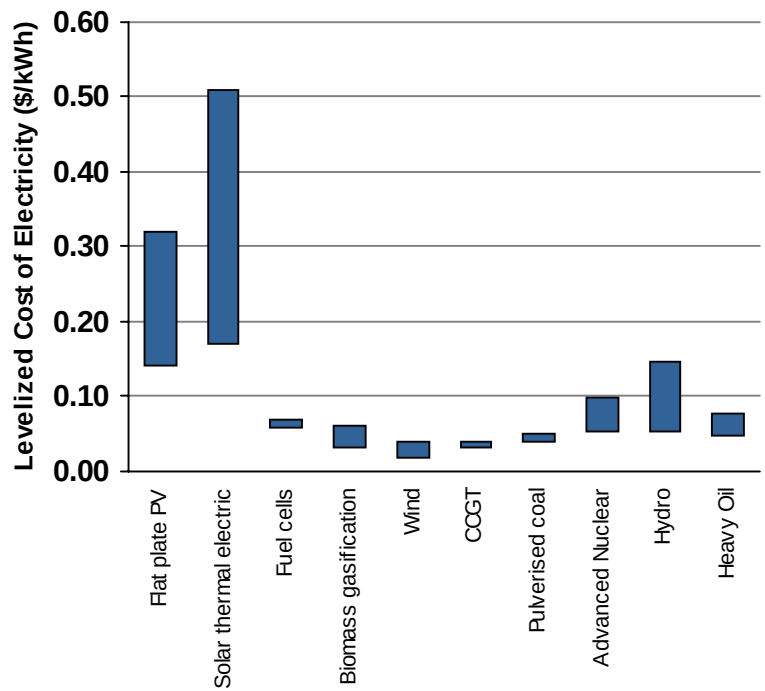
The Approach

- Evaluate the competitive position of wind power technology to other power generation technologies
- Define the wind power value chain
- Identify key players along the value chain
- Assess our client's strengths relative to the competitors
- Develop list of key success factors and likely future developments in the industry
- Propose a preferred market entry strategy

The Result

Our client is seriously considering entering the wind energy business.

Future Competitiveness of Wind Power (2010)



For a Middle East renewable energy fund, ADL reviewed the strategy for a renewable energy business.

The Challenge

To assess the viability of a renewable energy fund

The Approach

- Assess key technology and market assumptions of the strategy
- Interview renewable power project developers to understand the likely range of returns for their investments and the factors that drive returns
- Assess market, technology, and project risk

The Result

The client refocused their wind and PV strategies on the most attractive applications and markets, and is currently raising capital for the fund

ADL developed a market entry strategy for a leading energy company to enter the wind business.

The Challenge

To develop an appropriate market entry strategy for a leading energy company to enter the wind business

The Approach

- Analyse all segments of the value chain to identify segment characteristics, market size, margins and key success factors
- Understand management aspirations for the market entry and assess current internal competence
- Identify and profile all large companies in target segments
- Screen and rank all potential targets using an attractiveness/fit model

The Result

Target companies for partnership/acquisition have been identified that would position the client strongly

For three U.S. electric utilities, developed business plans for implementing geo-exchange heat pump programs.

The Challenge

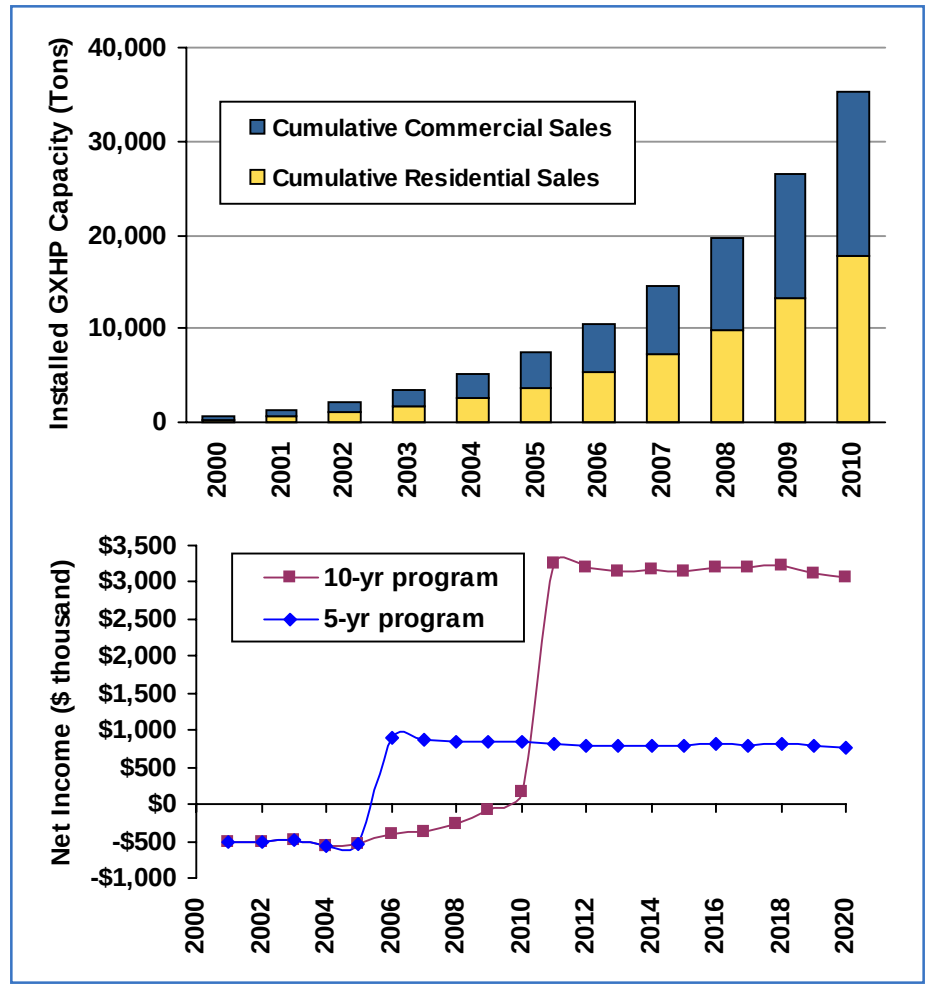
Assist utilities in developing a strategy and implementation plan for geo-exchange programs within their service territories.

The Approach

- Developed vision and goals for the GXS program
- Reviewed a range of options for implementation
- Assessed program economics
- Evaluated program role and linkages to other programs and corporate objectives
- Developed detailed income statements and assessed program benefits to utility
- Assessed implementation options and issues (e.g., trade ally infrastructure, market development)
- Prepared report and presentation materials to assist utility staff in implementation and in obtaining corporate support for program

The Result

All three utilities are in the process of implementing the geo-exchange programs.



We are now working with the US Department of Energy to develop a strategy to triple the use of biomass in the U.S. by 2010.

The Challenge

On August 12, 1999, President Clinton issued Executive Order 13134 with a goal to triple the use of bio-based products and bio-energy in the U.S. by 2010

The Approach

- Reviewed all potential products that could be made from biomass, including electricity, heat, fuels and industrial materials
- Developed an analytical model to compare the market size, environmental and economic impacts of each alternative.
- Used the results of the analytical model to inform a 10-year biomass strategy.

The Result

This project is now underway, and will be completed by January, 2001.

Corn Ethanol Plant, Bingham MN

For the US Department of Energy, ADL examined the potential for battery energy storage and fuel cells in building applications.

The Challenge

Falling prices in batteries, fuel cells and power electronics could make clean distributed energy storage and generation attractive in building applications. How should these systems be designed to maximize their economic and environmental value?

The Approach

- Developed an analytical tool to calculate the economic and environmental impacts of onsite energy systems in different building and geographic locations.
- Used the model to devise the optimal sizes and operating strategies for fuel cell and battery systems in multiple commercial buildings.
- Developed a tool to estimate the emissions of CO_2, NOx and SO_2 in the US as a function of the time of use, and used this tool to calculate the emissions impacts of fuel cells and battery energy storage.
- Identified the ways in which utility-industry restructuring could fundamentally change the optimal operating strategies for distributed resources.

The Result

The project identified rate structures as the single largest uncertainty facing distributed generators, as it affects the overall economics and the system design for all distributed power generation and storage technologies.

For the past six years, ADL has been the lead peer reviewer of the DOE's Energy Efficiency and Renewable Energy (EERE) programs.

The Challenge

To assess the credibility of DOE's Government Performance and Results Act (GPRA) energy saving and emission reduction estimates for all of the programs within EERE, and to assess program goals and activities for consistency with these benefits

The Approach

Review performance and cost trends for:

- Biomass technologies
- Photovoltaics
- Solar thermal
- Wind
- Fuel cells
- Geothermal
- Hydroelectric

The Result

DOE has reviewed their estimates and submitted new budget and impact numbers to Congress in all five years

For the UK Department of Trade and Industry (DTI), ADL identified cost reduction opportunities for five PV module technologies and BOS.

The Challenge

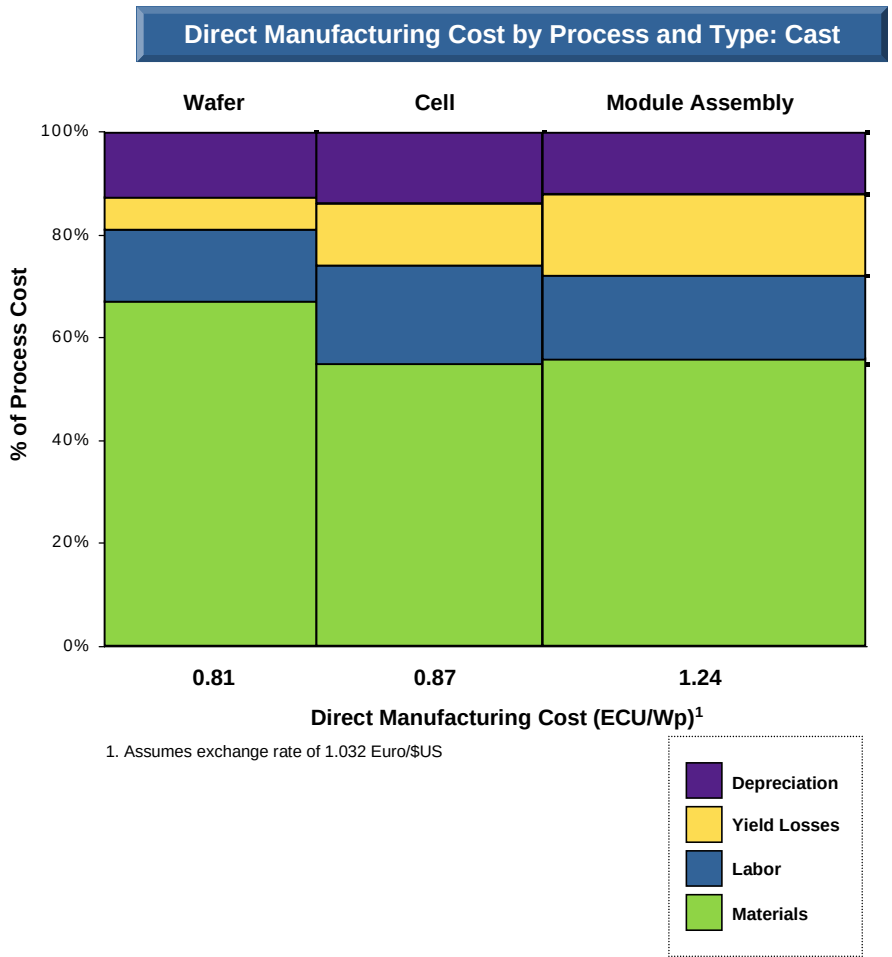
To provide a snapshot of current PV costs and identify cost-reduction opportunities that DTI could help fund

The Approach

- Utilize proprietary bottoms-up PV manufacturing cost models for five technologies (single-and poly-crystalline silicon, CdTe, CIS, and amorphous-Si
- Interview industry participants to verify bottoms-up analysis and to identify potential cost-reduction opportunities
- Prioritize cost-reduction opportunities by evaluating their impact using the costing models
- Recommend supporting policies to DTI

The Result

The Department of Trade and Industry will develop its photovoltaic program with a full understanding of where it can have the largest impact



ADL supported a European government in developing a technology strategy for CO_2 neutral transportation and heating fuels.

The Challenge

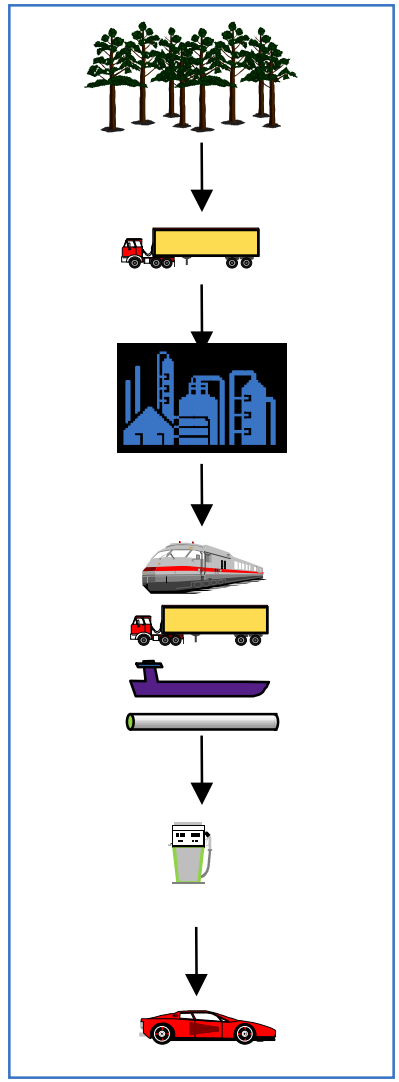
To identify which fuel chains the Dutch government should support to achieve a trend reversal in emissions of greenhouse gases.

The Approach

- Identify all plausible substantially CO_2 neutral fuel chains
- Analyze chains with respect to emissions, technical feasibility, cost, socio-economic impact, societal support
- Identify options that the government could focus on
- Test options against a range of possible scenarios
- Distill a strategy and business plan that is robust and effective

The Result

A clear direction for a technology program based on a solid analysis and selection program.



For DOE and EPA, ADL conducted a visioning session to help build consensus on actions and policies that could be used to accelerate renewable energy deployment.

The Challenge

To identify ways in which renewable energy technologies could play a major role in greenhouse gas reduction and urban air quality improvement

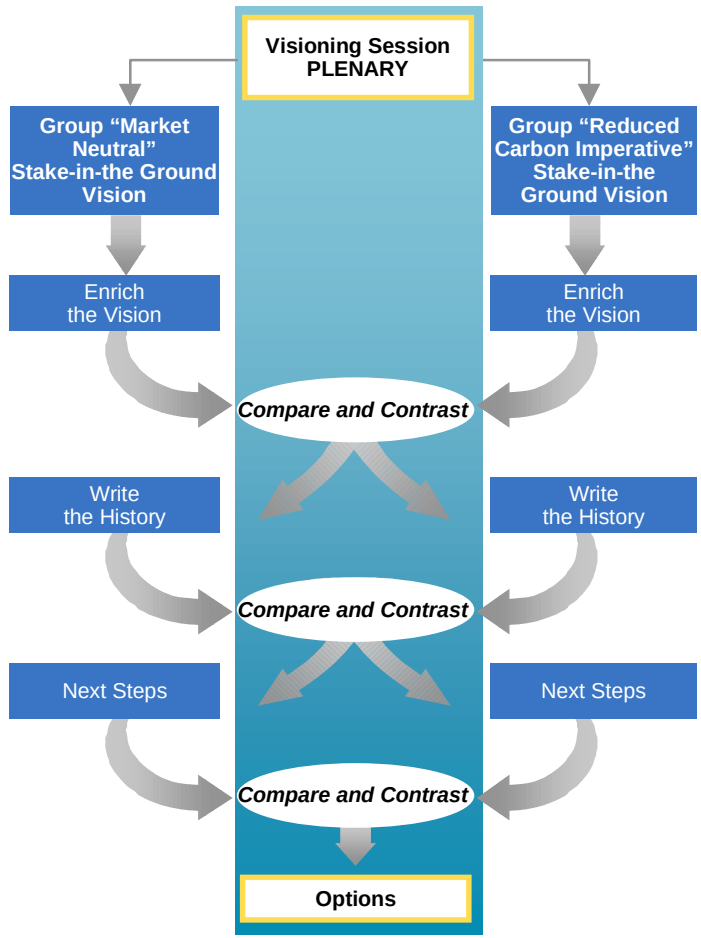
The Approach

- Collect diverse inputs from participants
- Look at scenarios of possible futures
- Facilitate a visioning session that would create a timeline working backwards from a desired end-state
- Identify near-term actions and key milestones

The Result

The visioning workshop made measurable progress toward defining near-term federal actions to enable the market success of renewable technologies over the next 25 years

Visioning Workshop Structure



We assisted a major utility in an assessment of the potential for building integrated photovoltaics (BIPV).

The Challenge

To determine the potential impact of BIPV in a major utility service territory

The Approach

- Assess the current building stock
- Assess BIPV output (monthly, peak, during utility peak days) given solar access issues
- Determine best geographical locations for BIPV
- Provide summer peak day generation shapes for pitched and flat roof buildings
- Determine ideal BIPV product types given roofing materials and construction type

The Result

The utility now has an assessment of the technical potential impact that BIPV can have in reducing their peak loads. They also have identified which areas/buildings to target initially for BIPV installations